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Assessing Different Freeway Interchange Design Impacts on Traffic Emissions and Fuel Consumption through Microsimulation

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ASSESSING DIFFERENT FREEWAY INTERCHANGE DESIGN IMPACTS ON TRAFFIC EMISSIONS AND FUEL CONSUMPTION THROUGH MICROSIMULATION

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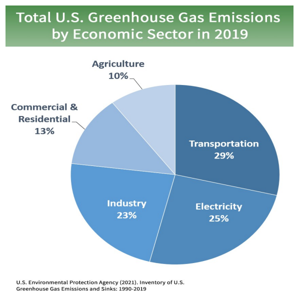
Abstract

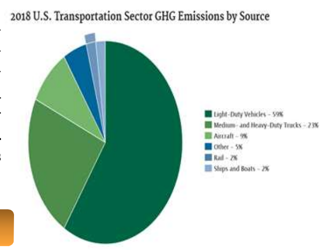
- In this study, the environmental performance of an existing service interchange, a CDI, is compared with two other different alternative designs, a Diverging Dimond Interchange DDI and a Single Point Urban Interchange SPUI, in terms of fuel consumptions, emissions, and traffic operations through simulations analysis utilizing PTV Vissim. We are primarily focused on major pollutants, including CO2, CO, and NOx.

Introduction

- Changes in the earth's climate are most likely the result of human activities, primarily fossil fuel burning, which causes the increase of the heat-trapping Greenhouse Gases and, consequently, raises the average global temperature of the earth.(2)
- According to the Inventory of U.S greenhouse gas emissions 2018, transportation with 29% ranks the largest contributor to GHGs, followed by the electric power industry with 25% and industry with 23%, as the main contributors. The rest of the GHGs are emitted by agricultural and commercial, and residential, with 23% in total GHGs.(1)
- The share of greenhouse gas emissions from transportation sources includes Carbon Dioxide CO2, which accounts for 97%, and it is by far the highest emission from the transportation sector. A relatively small amount of Methane (CH4), nitrous oxide (N2O), and various hydrofluorocarbons (HFCs) are emitted during fuel combustion. CO2, CH4, and N2O are all emitted via fossil fuel combustion, while HFC emissions result from leaks and end-of-life disposal from air conditioners.



- Within the transportation sector, light-duty vehicles, including passenger cars and light-duty trucks, are the largest contributor. Light-duty vehicles account for 59%, followed by medium and heavy-duty trucks with 23%, which accounts for 82% of emissions emitted from on-road vehicles. The remaining greenhouse gas emission comes from other modes of transportation.

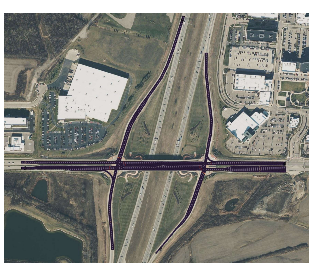


Literature Review

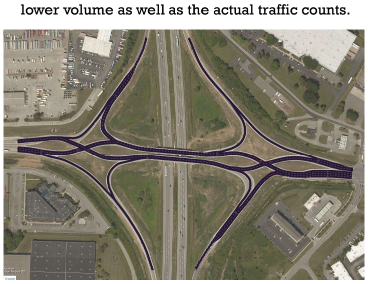
- Recently Environmental impact of transportation sector has drawn so many attentions. Highways are usually designed with higher standards, yet the interchanges are critical locations in terms of safety and performance due to increased traffic conflicts in those areas. However, interchanges are also essential elements of road networks in terms of air quality impact, and their control type, and geometric configuration can significantly affect vehicular emissions. (3)(4)
- Carbon Monoxide (CO): CO enters the atmosphere when carbon fuel is not burned completely, especially at low temperatures. Mobile sources both, On-road and non-road vehicles, are the primary CO source, especially in the cities, and it goes up to 95% of CO emission sources. We experience a high concentration of CO where heavy traffic congestion occurs.
- Nitrogen Oxides (NOx): Nitrogen Oxides are a family of seven poisonous gases that usually emit from burning fuel at high temperatures. This emission shows during agricultural and industrial activities as well as other human activities.

Methodology

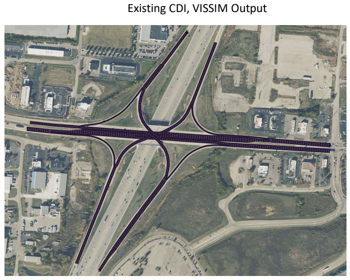
- The PM peak hour traffic counts were obtained from the Ohio Department of Transportation for the existing CDI model, and the same counts were used for all the models.
- PTV Vistro 2020 was utilized to do the optimizations of signal timing for all the interchanges.
- Traffic simulation and emission modeling occurred in PTV Vissim 2020. All the network characteristics have been kept similar throughout the models, and interchanges are being analyzed for 20% higher and lower volume as well as the actual traffic counts.



Existing CDI, VISSIM Output



DDI, VISSIM Output

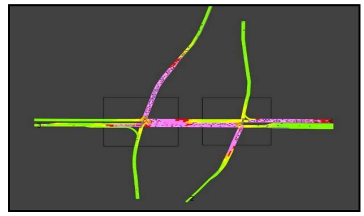


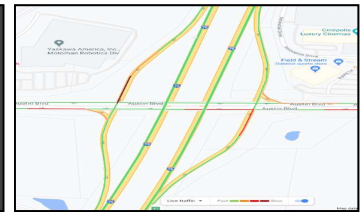
SPUI, VISSIM Output

Acknowledgments:

This poster was possible because of the kind support and help of my advisor, Dr Eustace. And I like to express my gratitude to Dr Zephaniah for guiding me along the way.

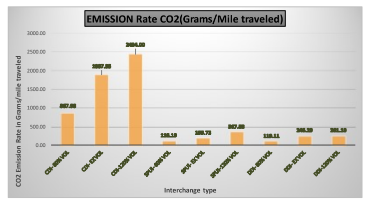
- To calibrate the existing model, we compared a heatmap created in Vissim based on the network's current speed against Google's live traffic and OHIOGO.

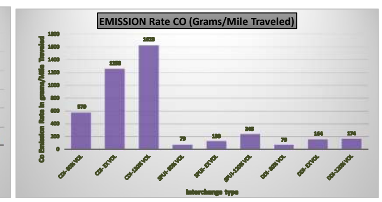




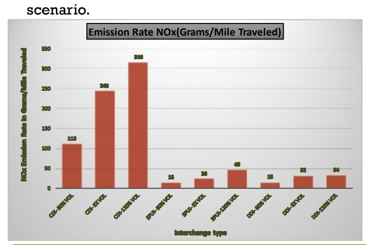
Result and discussion

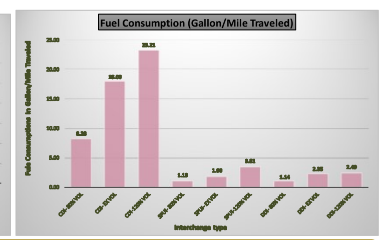
- The emission values have been normalized by dividing each value by total vehicle mile travel VMT for each scenario. Thie normalizations help better understand the relationships between the emission rates and the individual design alternatives.
- As the charts indicate, the rates of emissions are much higher in the existing CDI than the other two alternative designs, SPUI and DDI. A reduction of 85% on average for both alternative designs compare to the existing CDI has been calculated.





- However, within each design scenario, the 20% lower and higher volume, we observe a 45% reduction with 20% lower volume and 30% increase with 20% higher volume in all emission rates at the existing CDI scenarios.
- Similarly, for the SUPI, a 59% reduction in all emissions for the lower volume and an 80% increase in the higher volume scenario.
- And for the DDI, we see a 48% reduction in lower volume and only a 6% increase in higher volume scenario.





Conclusion and recommendation

- According to the result, the DDI and SPUI have better performance in terms of average queue length and vehicle delays in the entire network. They also perform higher average speed and less stop delays than the existing CDI, resulting in a better Level of Service due to less congestion. Consequently, we observe much better emission rates and fuel consumption in alternative design than the existing CDI.
- The environmental impacts of interchanges are as significant as safety and operational performances. They need to be accounted for as we all hope to pass the gift of life to our future generations.

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